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TECHNICAL REPORT No. 79

Preliminary Assessment of p-Nitro-N-Methylaniline as Stabiliser in CDB Propellants (C)

G A Palmer

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Technical Report No 79

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August 1971

Preliminary Assessment of p-Nitro-N-Methylaniline as Stabiliser in CDB Propellants (C)

by

G A Palmer

SUMMARY

A review has been made of the results of tests on cast double-base propellants containing para-nitro-N-methylaniline (NMA) as a stabiliser. The review is based on 80°C Silvered Vessel (SV) tests and stabiliser consumption trials carried out at both ICI and ERDE. The available evidence shows that NMA is adequate as a replacement for 2-nitrodiphenylamine (NDPA) for some uses although not as good in ultimate stabilising power. An initial one per cent minimum of NMA may be suitable as sole stabiliser in conventional double-base propellants but slightly more may be required for unfavourable compositions or where a Service Chemical Life much in excess of 10 years at 32°C is required. It is found that composite modified compositions require resorcinol in addition to NMA for adequate chemical stability. Clarification is needed of Land Service requirements to enable the required figures for Service Chemical Life to be specified.

Further copies of this technical report can be obtained from Defence Research Information Centre, Station Square House, St Mary Cray, Orpington, Kent. BR5 3RE

CONTENTS

Reference: WAC/189/01

1 INTRODUCTION

This subject has been reviewed at the request of the CDB Working Party and the results summarised in this report represent some years of mainly routine work. The first experimental large cast double-base (CDB) charges made in the UK showed poor storage potential owing to internal cracking being caused by gas accumulation on hot storage, and this problem was found to become more serious when additives such as sucrose octa acetate (SOA) were included to reduce the burning rate.

Laboratory work at ERDE and elsewhere[1,2] had shown that the main cause of propellant rupture was nitrogen gas, due to its low solubility in the propellant and slow diffusion to the outside of the charge. Various ingredients reacted with the nitric esters and their decomposition products to give nitrogen, so that it was necessary to reduce their amounts greatly, or to eliminate them altogether. Of the usual stabilisers, carbamite gave the most gassing, 2-nitrodiphenylamine (NDPA) gave less gassing in some compositions but it was not universally satisfactory. In addition, NDPA tended to give higher burning rates, and was liable to give "blooming" during hot storage if used in amounts around 2 per cent.

When para-nitro-N-methylaniline (NMA) is involved, the para-nitro group polarises the methyl substituted amino group, thus minimising the denitration of nitric esters. This was demonstrated by American work[3] which showed a negligible change in the viscosity of nitrocellulose in a single-base composition stabilised with NMA, and elimination of nitrogen evolution from the stabiliser reaction with NO_2. NMA was first proposed for use in UK CDB propellant by ICI who had used it in other double-base propellants many years earlier. It was introduced into the AID series of propellants via the casting powder to improve the cracking life of the Foxhound sustainer charge for Seaslug Mark I. At the time it was considered wise and it was also convenient, to have some NDPA in the CDB by retaining NDPA as stabiliser in casting liquids. Since this successful application, the use of NMA has been steadily extended to other casting powders, especially those used for modern case-bondable compositions where escape of gas is restricted because the propellant is bonded to the motor case. Apart from some experimental compositions, NDPA has been generally used as stabiliser in the casting liquid. Although the solubility of NMA is only 1.67 per cent in 75 NG/24 TA casting liquid at 21°C,[4] experiments at ERDE at an NMA concentration of 1.0 per cent, which is the normal concentration for stabiliser in casting liquid, have shown that no recrystallisation occurs down to -20°C, so that its solubility is adequate at this level. It should be emphasised that this report deals with the properties of propellants in simple systems; the presence of new types of inhibiting materials will introduce further complications which in general tend to lower chemical stability of the propellant unless special attention is devoted to these aspects.

2 RESULTS

The results available from a number of Silvered Vessel (SV) and storage tests are given in the attached Tables.

Table 1. SV test results at 80°C when various proportions of current stabilisers and NMA replace Mineral Jelly in the cordite Mk I composition (ICI Ardeer).

Table 2. SV test results at 80°C when cordite Mk I is heated with pure NMA and with added typical impurities (ERDE).

Table 3. Small SV and Sealed Bottle test results at 80°C with typical compositions with current stabilisers and NMA in the presence of pyritic particle contamination (ERDE).

Table 4. SV test results at 80°C with typical case-bondable compositions of ATN and BDI types containing NMA as sole and joint stabiliser (ERDE).

Table 5. Residual stabiliser contents after storage of ATN variants, modified BDI(D1), and CRU compositions containing NMA, for up to 24 weeks at 70°C. These tests were conducted on cast propellant cut into ¼ inch pieces stored in a glass bottle with a foil-covered cork carrying a fume tube. (ICI Ardeer.)

Table 6. Residual stabiliser content after storage of BDI, ATN, AID and ARA variants for up to 12 months at 60°C or 24 months at 49°C. (Propellants manufactured at IMI Summerfield and at ERDE are indicated by "IMI" or "CPA" respectively.) Most of the charges in these tests were 150 mm in diameter and inhibited with cellulose acetate, and were stored vertically inside a closely fitting aluminium tube with tight-fitting polythene end-caps, except as indicated at the foot of the table.

Table 7. Compositions of propellants quoted in this Report. The available results involve compositions under development for weapon applications rather than special compositions to assess NMA in particular.

3 DISCUSSION

3.1 Silvered Vessel and Sealed Bottle Tests

In the standard 70 gram SV test at 80°C with Mark I cordite containing 5 per cent mineral jelly as stabiliser, the normal SV figure as indicated by brown fumes or a 2 degC temperature rise is between 500 and 600 hours. Although lower figures than this have been obtained in some tests (eg 224 - 268 in Table 1) they were associated with experimental Mark I cordite, and are not regarded as typical; nor is the low figure of 292 hours with 1 per cent NMA replacing the mineral jelly in a Mark I cordite mix (P 33398, Table 1). In general, the results indicate that 1 per cent NMA as the sole stabiliser in a Mark I cordite mixture is about equivalent to 5 per cent mineral jelly as stabiliser. Carbamite gives about twice the SV figure, and NDPA slightly

more. However, in the case of large propellant charges the poorer cracking life associated with NDPA, and particularly carbamite, prevent full advantage being taken of the increased ultimate stabilising power. Table 1 also shows that lead compounds themselves often have stabilising properties, which vary with the type of compound.

In another series of tests (Table 2) 5 per cent of NMA added to Mark I cordite was shown to improve the SV figure considerably. The presence in the NMA at 0.2 and 1 per cent level of **p-nitroaniline** as a potential impurity had only a small effect.

The miniature SV tests (15 - 18 g samples) (Table 3) give higher figures than the standard test which involves 70 g samples in correspondingly larger vessels. Considered on a comparative basis, the miniature SV tests show that NMA at a level of 0.5 per cent in compositions having a high NC content and containing lead 2-ethyl hexoate, gives lower SV figures than carbamite or NDPA in the presence of pyritic particle contamination, which is known to cause local decomposition centres in the contaminated double-base propellant. The SV figure is reduced by 29 per cent (CPA 2352/3) in contrast to the virtually unchanged figures given by compositions stabilised with carbamite or NDPA. In an AID composition containing NMA/NDPA the SV figure was reduced by nearly 22 per cent in the presence of pyritic particle contamination (CPA 2383/4). The sealed bottle tests (Table 3) show NMA to compare favourably with carbamite or NDPA, but the results are not so consistent as the, generally lower, figures given by the miniature SV tests. The situation is complicated further by the presence of lead compounds, lead 2-ethyl hexoate in the first 6 compositions, and lead stearate in the AID-type compositions. Table 1 shows that both these lead compounds have stabilising power in a double-base matrix. Hence it cannot be stated categorically that NMA on its own would deal with pyritic particle contamination. However, the chances of pyritic particle contamination occurring during modern manufacture of propellants is remote, and in the event all conventional CDB propellants contain one or more lead compounds. The special case of composite modified cast double-base (CMCDB) is discussed under Section 3.2.2.

SV tests on the low nitrocellulose case-bondable CDB such as ATN-type compositions (Table 4) show that 1 per cent NMA as sole conventional stabiliser compares satisfactorily with the 1 per cent NDPA originally used and the 0.7 per cent NMA, 0.3 per cent NDPA combination arising from the usual NDPA-stabilised NG/TA casting liquids. The comparison is less favourable with the BDI-type compositions where the SV figure for the NMA/NDPA stabilised BDI-type propellant is less than half that of NMA/NDPA stabilised ATN-type compositions, and, for the NMA-stabilised BDI-type propellant only one third to one fifth that of the ATN-type compositions stabilised with 1 per cent NMA. However, 600 hours may be regarded as adequate for some usages. Also, some Ardeer vacuum flask tests at 80°C (not reported in detail) have given results in the region of 2000 hours for BDI-type compositions, but a direct comparison between the two locations cannot be made readily as there are differences from the standard ERDE Silvered Vessel procedure.

The greater stability shown at ERDE of the ATN-type propellant in contrast to the BDI-type propellants may be due to the superior stabilising effect of the easily nitrateable lead salts in the ATN.

3.2 Service Chemical Life from Stabiliser Consumption Tests

3.2.1 Standards

Well established temperature coefficients are lacking for the newer stabilisers, and in this report estimates of life at the test temperature are quoted together with a calculated value for storage at 32°C (90°F). The following temperature coefficients are assumed on the basis of 1.8 for 5.5 degC (10 degF) for up to 49°C and 2 for 5.5 degC (10 degF) above 49°C.

70°C to 60°C	3.5
60°C to 49°C	4.0
49°C to 32°C	6.1

In the Ardeer work (Table 5), a fume venting tube was provided for the cut propellant samples, there was no cellulose acetate inhibition, and no close confinement of a propellant mass. The ERDE propellant packing in closed tubes is thought to be closer to Service rocket charge conditions, and it is considered that valid estimates can be made for Service Chemical Lives from Table 6. Unfortunately no identical samples were tested, so that a direct comparison is not possible between the two sets of conditions. Consequently the results of Table 5 have been regarded as self-comparative.

As far as chemical stability is concerned, Service Chemical Life has been defined as the time at which the stabiliser is reduced to half its initial value, so that the amount of the residual stabiliser will depend upon the initial level. For newer propellants with low stabiliser contents it is probably better to consider Service Chemical Life in terms of the minimum level of residual stabiliser.

The following arbitrary criteria for the end of Service Chemical Life have been used for Table 6:

Residual NMA below 0.5 per cent (as reaction products are regarded as having little stabilising power).

Residual NDPA below 0.2 per cent (as reaction products have stabilising power).

Residual NMA and NDPA totalling 0.3 per cent (when the initial amount of NDPA is not less than 0.3 per cent).

It should be emphasised that the conclusions drawn depend upon the reliability of sampling and chemical analysis for determining these small amounts of stabiliser in aged propellants. It has also been noticed that there is visual bleaching of aged propellant near surfaces exposed to the air, which requires further study.

3.2.2 Conclusions from Table 5

Compositions of the ATN-type with one per cent NMA only (Items 1 - 4) show acceptable residual stabiliser figures after 12 to 16 weeks at 70°C: there were no ignitions in 24 weeks at 70°C. The addition of 0.6 per cent resorcinol reduces the rate of NMA stabiliser consumption, so that the estimated Service Chemical Life would be equivalent to 19 weeks at this temperature.

One per cent NMA alone seems an unsuitable stabiliser for composite modified double-base formulations (Items 12 and 13) but the addition of 1.0 per cent of resorcinol doubled the estimated Service Chemical Life for the casting powder and trebled that for the cast propellant at this temperature (Items 15 and 14 respectively).

3.2.3 Conclusions from 6-inch Charges (Table 6)

The recent practice to obtain maximum resistance to cracking has been to use NMA in proportions ranging from 0.6 to 1.3 per cent with 0.3 per cent NDPA from the casting liquid. In propellants containing mixtures with NDPA, NMA reacts preferentially so that the concentration of NDPA is relatively constant until most of the NMA is used up. Thus stabilisation is effectively due to NMA for most of the Chemical Safe Life so that the stabilising reactions of NMA have the predominant effect on propellant cracking caused by internal gas evolution. Items 6 and 7 show that resorcinol also reacts preferentially to NDPA and will act with NMA in having the predominant effect on propellant cracking. Only one composition with NMA as sole stabiliser has been tested. Service Chemical Lives have been estimated graphically using the criteria given in Section 3.2.1, and are summarised below.

Item No	Composition Type	Stabiliser, %		Estimated Service Chemical Life			
				Months at		Years at	
				60°C (a)	49°C (b)	32°C (a)	32°C (b)
4	BDI(D1)	NMA	1.2	9	26	18	13
3	BDI(D2)	NMA NDPA	0.6 0.4	5	27	10	13½
10,12	AID(M15)	NMA NDPA	1.1 0.3	11,10	59*,39*	22,20	30,20
14,15	ARA(D4)	NMA NDPA	1.3 0.3	11,11	46½*,47½*	22	23½,24
18,19	BDI(D1)/ARA(D4) Blends (SRS 38/15 & 20)	NMA NDPA	0.8 0.3	7½,7¼	42*,42*	15	21
7	ATN(D27)	NMA NDPA Resorcinol	0.6 0.3 0.7	10¾*	46½*	22	23½

*Extended extrapolation

One low result from AID(M15) type compositions has been recorded on an IMI charge (Item 9) but this does not follow the normal pattern for the rate of consumption of NDPA, and unfortunately only one figure is available after 29 months at 49°C. An approximate estimation suggests a life of the order of 13 years at 32°C for this sample. This figure is regarded as abnormal for AID variants. In general, estimates of life at 32°C from the trials at 49°C and 60°C agree reasonably in view of the considerable extrapolations required in most cases to estimate the life at 49°C from the two-year results at this temperature.

In the cases of Items 7, 12 and 13, the six-inch diameter solid charges have cracked internally at 60°C before the end of Service Chemical Life. This effect, arising from internal gas evolution, is a separate consideration and varies with composition and charge design, and also the hot storage requirements of the rocket motor, but it would be a limiting factor for some charges. The only test with NMA as sole stabiliser, 1.2 per cent in BDI(D1), suggests a Service Chemical Life of 13 to 18 years at 32°C.

The tests at 49°C with ATN(D27) suggests a Service Chemical Life of 23 years at 32°C.

A good Service Chemical Life is also obtained for the AID(M15)-type propellants, and in fact there have been no adverse reports on their chemical stability under Service conditions, ie in Foxhound and Wolfhound motors. ARA(D4) propellants indicate an equally good Service Chemical Life.

3.2.4 Service Requirements

The Naval Service has detailed the probable Service history of certain GW motors such as Retriever, and a suitable Service Chemical Life can be deduced.

In the Land Service the periods of use and storage under the various specified environments are not clearly defined, and WOPS 100 represents extreme ambient temperatures for tropical conditions. The current Technical Requirements for the Land Service Troy motors involve packaged storage for $2\frac{1}{2}$ years (with possible extension to 3) at a cycle between 32 and 60°C which might be equated thermally to about 49°C, or assuming the accepted temperature coefficient, to about 15 or 18 years at 32°C. It is important that this requirement should be clearly defined since the present results indicate that whilst ATN(D27) is acceptable, the Service Chemical Life of BDI(D2) would be less than 15 years at 32°C on the basis of the proposed criteria. IMI Summerfield has reported "bleaching" of propellants beneath the blue Hypalon inhibition* of the Pointer charge, extending inwards to a depth of about 1 inch. The "bleaching" is associated with depletion of NMA stabiliser (nominal 0.8% NMA, 0.3% NDPA) and enhanced burning rate. The phenomenon is not yet understood, but it is thought that the "bleaching" effect is due to the formation of an almost colourless nitroso derivative of the NMA which appears to be more rapidly depleted in the peripheral regions of the charge. Aerial oxidation may be a factor. It is well known from earlier work that a limited access to air gives the greatest rate of stabiliser consumption and development of acidity in carbamite cordites, as compared with no air or unlimited air. There is also some recent evidence that NMA migrates readily into blue Hypalon (CL8436) inhibition at the expense of the peripheral regions of the propellant charge, in which case the Service Chemical Life of a rocket charge may be less than that of the propellant, either on its own, or coated with the "traditional" cellulose acetate which is considered in this Report.

Further work is clearly necessary with specific compositions including new inhibitors etc and to determine temperature coefficients for the newer stabiliser combinations. The usage of Land Service weapons under the various specified environments requires further consideration in Technical Requirements so that the required Service Chemical Life for a given motor and propellant can be defined.

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*Not used in latest design.

4 CONCLUSIONS

4.1 NMA reacts preferentially to NDPA, and is not as good as carbamite or NDPA in ultimate stabilising power.

4.2 For NMA as sole stabiliser the minimum initial concentration will depend upon the propellant composition, and the Service usage required. In favourable circumstances, under Naval storage conditions, the minimum could be as low as 1.0 per cent, particularly in the presence of stabilising lead compounds. However, if a Land Service Life requirement of more than about 13 years at 32°C is required for the BDI-type propellant, the NMA content would need to be increased to say 1.5 per cent, or alternatively augmented with resorcinol if this were acceptable ballistically.

4.3 NMA alone is unsatisfactory for use in composite modified double-base propellants but it appears that the required stability might be obtained in combination with at least an equal amount of resorcinol. Work on other combinations is in hand.

4.4 Extensive stabiliser consumption tests should be carried out on novel NMA-stabilised compositions proposed for Service use, in order to cover possible adverse effects arising from the use of new ingredients, the omission of ingredients with supplementary stabilising properties, and to cover locations close to the inhibitor and charge surface.

4.5 Current compositions suggested for Land Service use should be reviewed carefully since it is indicated that, on the criteria in this Report, some BDI-types hardly meet the required Service Chemical Life of 15 to 18 years at 32°C implied by the Troy Technical Requirement.

4.6 Greater precision is required in Land Service Technical Requirements to decide the safe Service Chemical Life required for the propellants.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

1	Rosser R J	ARE Report No 19/49, December 1949
2	Davies N	ERDE Report No 10/R/58, June 1958
3		USP 2,696,430
4		Private communication, Research Department, ICI (Nobel Division) Stevenston, Ayrshire, dated 11 10 57

TABLE 1

ASSESSMENT OF STABILISER PERFORMANCE BY SV TEST AT 80°C

Sample Reference No (Ardeer)	Additives replacing Mineral Jelly in Cordite Mk 1	SV at 80°C (hours to brown fumes)
P33398	1% NMA	292
P33395	1% NMA + 5% lead 2-ethyl hexoate	1192
P33396	1% NMA + 5% lead citrate	712
P33397	1% NMA + 5% lead carbonate	1864
P33533	1% NMA + 7.5% adiponitrile	1040
ST1	1% carbamite	1056
ST2	2% carbamite	1850
ST3	3% carbamite	2000
ST4	5% carbamite	1972
ST16/0	5% mineral jelly (control)	268
ST5	1% NDPA	1228
ST6	2% NDPA	> 2000
ST7	3% NDPA	> 2000
ST8	5% NDPA	> 2000
ST16/1	5% mineral jelly (control)	264
ST9	1% NMA	528
ST10	2% NMA	616
ST11	3% NMA	678
ST12	5% NMA	1030
ST16/2	5% mineral jelly (control)	526
ST13	0.5% carbamite, 0.5% NDPA	1152
ST14	0.5% carbamite, 0.5% NMA	720
ST15	0.5% NDPA, 0.5% NMA	624
ST16/3	5% mineral jelly (control)	224
ST17	2% NMA, 0.5% carbamite	944
ST18	2% NMA, 0.5% NDPA	836
ST23	0.5% NMA, 0.5% NDPA, 0.5% carbamite	1028
ST27/0	5% mineral jelly (control)	504
ST19	2% carbamite, 0.5% NMA	1916
ST20	2% carbamite, 0.5% NDPA	1604
ST21	2% NDPA, 0.5% carbamite	> 2000
ST22	2% NDPA, 0.5% NMA	1772
ST27/1	5% mineral jelly (control)	492

/continued

TABLE 1 (continued)

Sample Reference No (Ardeer)	Additives replacing Mineral Jelly in Cordite Mk 1	SV at 80°C (hours to brown fumes)
ST24	5% lead stearate	1252
ST25	5% lead carbonate	964
ST26	5% white lead	1432
ST27/2	5% mineral jelly (control)	504

TABLE 2

ASSESSMENT OF THE EFFECT OF p-NITROANILINE IMPURITY IN NMA BY SV TEST AT 80°C

Sample Details (ERDE)	SV at 80°C (hours to fume)
Cordite Mk I (WACX 995) control	626
Cordite Mk I + 5% pure NMA	1906
Cordite Mk I + 5% NMA containing 0.2% p-nitroaniline	1842
Cordite Mk I + 5% NMA containing 1.0% p-nitroaniline	1842
Cordite Mk I + 5% pure p-nitroaniline	832

TABLE 3

ASSESSMENT OF STABILISER PERFORMANCE AT 80°C IN THE PRESENCE OF PYRITIC PARTICLE CONTAMINATION

(1) By SV Test (15 - 18 g sample)
(2) By Sealed Bottle Test (40 g sample piece)

Sample Details (ERDE) CDB Propellants	Test at 80°C (hours to fume)	
	(1)	(2)
Carbamite stabilised - control - CPA 2349	2009	1440
Carbamite stabilised - with pyritic particles CPA 2348	2016	2640
NDPA stabilised - control CPA 2351	1659	3050
NDPA stabilised - with pyritic particles CPA 2350	1736	1920
NMA stabilised - control CPA 2353	2043	1248
NMA stabilised - with pyritic particles CPA 2352	1448	1248
AID(M11)/5 - carbamite stabilised - control CPA 2385	3388	3408
AID(M11)/5 - carbamite stabilised - with pyritic particles CPA 2382	4152:3417	2496
AID(M15)/5 - NMA/NDPA stabilised - control CPA 2384	2516	3000
AID(M15)/5 - NMA/NDPA stabilised - with pyritic particles CPA 2383	1972	2664

NOTE ON TABLE 3

The first 6 compositions were all high in NC (63% pyro), low in stabiliser (0.5%), contained lead 2-ethyl hexoate, and were chosen to be as sensitive as possible to pyritic particle contamination as judged by past experience.

TABLE 4

ASSESSMENT OF NMA AS TOTAL AND PARTIAL STABILISER IN TYPICAL CASE-BONDABLE CDB BY SV TEST AT 80°C

Sample Details (ERDE) CDB Propellants	SV at 80°C (hours to fume)
ATN/19 (CPA 4055)	2136
ATN(Mod)/19 (Casting Powder NMA stabilised) (CPA 4775)	1968
ATN(Mod)/4(Mod) (ATN with NDPA completely replaced by NMA) (CPA 4543)	1896
ATN(D26)/19 (Casting Powder NMA stabilised) (CPA 5619)	2184
ATN(D26)/19(Mod) (NMA stabilised) (CPA 5645)	3048
BDI(D1)/25 (Mod_2) (CPA 5716)	840
BDI(D1)/25 (Mod_1) (NMA stabilised) (CPA 5717)	600

TABLE 5

STABILISER CONSUMPTION TESTS AT 70°C

Item No	Composition	Identification Number (Ardeer)	Platonising Agents (Lead Compounds)	Stabilisers		Residual Stabiliser (Per cent)					
						Weeks at 70°C					
				Names	Nominal (Per Cent)	0	4	8	12	18	24
1	ATN(D27) Casting Powder	S910	Salicylate β-Resorcylate	NMA	1.0	0.97	0.92	0.88	0.81	0.30	0.15
2	ATN(D27)/33	S915	Salicylate β-Resorcylate	NMA	1.0	1.05	0.88	0.65	0.54	0.21	0.03
3	ATN(D20)/33-Type	Y3705	Salicylate β-Resorcylate	NMA	1.0	0.92	0.88	0.56	0.68	-	0.17
4	ATN(D20)/33-Type	Y3707	Salicylate β-Resorcylate	NMA	1.0	0.91	0.80	0.49	0.70	-	0.17
5	ATN(D20)/47-Type	Y3706	Salicylate β-Resorcylate	NMA Resorcinol	1.0 0.6	0.90	0.88	0.58	0.72	-	0.34
6	ATN(D20)/47-Type	Y3708	Salicylate β-Resorcylate	NMA Resorcinol	1.0 0.6	0.89	0.84	0.52	0.72	-	0.38
7	ATN(D26)/4	Y3765 (5% Aluminium Present)	Salicylate β-Resorcylate	NMA NDPA	0.7 0.3	0.61 0.32	0.42 0.34	0.19 0.24	0.13 0.16	- -	0.05 0.11
8	ATN(D20)/33-Type	T2039 (DEP Present)	Salicylate β-Resorcylate	NMA NDPA	0.7 0.3	0.67 0.31	0.46 0.31	0.24 0.28	0.10 0.26	- -	0.05 0.20
9	ATN(D26)/4 + 1% Kieselghur	Y4130	Salicylate β-Resorcylate	NMA NDPA	0.7 0.3	0.73 0.24	0.50 0.19	0.54 0.16	0.38 0.14	- -	- -
10	ATN(D26)/47	Y4153	Salicylate β-Resorcylate	NMA NDPA Resorcinol	0.7 0.3 0.7	0.72 0.22	0.58 0.18	0.46 0.17	0.28 0.18	- -	0.03 0.18
11	BDI(D1)/25 + 1.3% Kieselghur	Y4120	Citrate Phthalate	NMA NDPA	0.7 0.3	0.70 0.24	0.42 0.22	0.36 0.21	0.28 0.18	- -	0.22 0.11
12	CRU-Type CMCDB	S854	None	NMA	1.0	1.08	0.88	0.27	0.26	(a)	
13	CRU-Type CMCDB Casting Powder	S855	None	NMA	1.0	1.18	1.19	0.49	0.41	0.27*	
14	CRU-Type CMCDB	S900	None	NMA Resorcinol	1.0 1.0	1.09	0.81	0.75	0.58	0.54	0.43
15	CRU-Type CMCDB Casting Powder	S905	None	NMA Resorcinol	1.0 1.0	1.02	1.03	0.90	0.83	0.42	0.41

Cast propellant stored as cut ¼-inch pieces in a glass bottle with a foil covered cork carrying a fume tube.

(a) Sample ignited after 17 weeks.

*Sample removed after 17 weeks due to low concentration.

TABLE 6

STABILISER CONSUMPTION TESTS AT 49°C AND 60°C

Item No	Composition	Identification Number (ERDE, except IMI)	Platonising Agents (Lead Compounds)	Stabilisers			Residual Stabilisers (Per cent)							
				Names	Per cent		Months at 49°C				Months at 60°C			
					Nominal	Control	6	12	18	24	3	6	9	12
1	BDI(D1)/25 (Mod$_2$)	CPA 5716 (49°C)	Citrate Phthalate	NDPA NMA	0.6 0.6	0.57 0.60		0.51 0.35	15 mths 0.50 0.36	0.39 0.15		0.51 0.30		0.18 <0.05
2	BDI(D1)/25 (Mod)	CPA 6362	Citrate Phthalate	NDPA NMA	0.55 0.65	0.54 0.60					0.51 0.40			
3	BDI(D2)/25	978 (49°C)) 980 (Control)) IMI 979 (60°C))	Citrate Phthalate	NDPA NMA	0.4 0.6	0.32 0.60	0.29 0.45	0.29 0.35	0.28 0.25	0.21 0.16	0.29 0.25	22 wks (cracked) 0.16 0.05		
4	BDI(D1)/25 (Mod$_1$) NMA in liquid and powder	CPA 5717	Citrate Phthalate	NMA	1.2	1.18		0.87	15 mths 0.80	0.55		0.8		0.23
5	BDI(D1) Mod + 2% Resorcinol in Powder/19 (Mod NMA for NDPA)	CPA 5327	Citrate Phthalate	Resorcinol NMA	1.3 1.0									0.67 0.40
6	ATN(D27)/47	CPA 6549 (49°C) CPA 6548 (Control) CPA 6550 (60°C)	Salicylate β-Resorcylate	Resorcinol NDPA NMA	0.7 0.3 0.6	0.64 0.32 0.65	0.56 0.35 0.55	0.39 0.31 0.37	0.34 0.31 0.40	0.50 0.30 0.32	0.50 0.32 0.50			
7	ATN(D27)/47	1004 (49°C)) 1006 (Control)) IMI 1005 (60°C))	Salicylate β-Resorcylate	Resorcinol NDPA NMA	0.7 0.3 0.6	0.52 0.33 0.60	0.57 0.32 0.50	0.40 0.32 0.40	0.33 0.31 0.40	0.45 0.30 0.37	0.40 0.32 0.40	20 wks (cracked) 0.17 0.30 0.40		
8	ATN(D27)/47	CPA 6361	Salicylate β-Resorcylate	Resorcinol NDPA NMA	0.6 0.3 0.6	0.50 0.34 0.60					0.43 0.33 0.40			
9	AID(M15)/5	E6769 (IMI)	Stearate	NDPA NMA	0.3 1.1	0.4 1.0				29 mths 0.05 0.15				
10	AID(M15)/5	CPA 6546 (49°C) CPA 6363 (Control) CPA 6547 (60°C)	Stearate	NDPA NMA	0.3 1.1	0.30 1.05	0.27 0.95	0.31 0.81	0.31 0.70	0.28 0.66	0.29 0.80	0.29 0.60	0.11 0.35	43 wks (cracked)

TABLE 6 (continued)

Item No	Composition	Identification Number (ERDE, except IMI)	Platonising Agents (Lead Compounds)	Stabilisers			Residual Stabilisers (Per cent)							
				Names	Per cent		Months at 49°C				Months at 60°C			
					Nominal	Control	6	12	18	24	3	6	9	12
11	AID(M15)/5	CPA 6363	Stearate	NDPA NMA	0.3 1.1	0.28 1.05					0.26 0.85			
12	AID(M15)/19	CPA 6557 (49°C) CPA 6556 (Control) CPA 6558 (60°C)	Stearate	NDPA NMA	0.35 1.00	0.35 1.00	0.32 0.85	0.31 0.68	0.31 0.60	0.29 0.45	0.34 0.70	0.31 0.30	34 wks (cracked) 0.24 0.15	
13	OIO(N2K)/5	CPA 6544 (Control) CPA 6545 (60°C)	Stearate	NDPA NMA	1.5 0.1	1.48 0.10					1.16 <0.05	23 wks (cracked)		
14	ARA(D4)/19	CPA 6602 (49°C) CPA 6601 (Control) CPA 6603 (60°C)	Stearate Phthalate	NDPA NMA	0.34 1.32	0.32 1.25	0.27 1.15	0.30 0.91	0.32 0.80	0.32 0.57	0.34 0.95	0.30 0.55	0.24 0.25	0.18 <0.05
15	ARA(D4)/19	1050 (49°C)) 1052 (Control)) IMI 1051 (60°C))	Stearate Phthalate	NDPA NMA	0.34 1.32	0.34 1.25	0.31 1.20	0.27 1.00	0.31 0.80	0.29 0.67	0.32 0.95	0.26 0.60	0.22 0.25	0.18 <0.05
16	ARA(D4)/19	CPA 7055 (49°C) CPA 7057 (Control) CPA 7056 (60°C)	Stearate Phthalate	NDPA NMA	0.3 1.3	0.35 1.30	0.34 1.15	0.33 1.10	0.34 0.85	0.31 0.83	0.34 1.10	0.31 0.80	0.26 0.50	0.25 0.30
17	ARA(D4)/19	CPA 6360	Stearate Phthalate	NDPA NMA	0.3 1.3	0.33 1.25		0.30 0.90	15 mths 0.30 1.0	0.29 0.80	0.30 1.10	4½ mths 0.29 1.03	6 mths 0.29 0.90	7½ mths 9 0.33 0.21 0.80 0.65
18	SRS38/20/19 (BDI(D1) 80% / ARA(D4) 20% / 19)	CPA 6708 (49°C) CPA 6707 (Control) CPA 6709 (60°C)	Citrate Phthalate Stearate	NDPA NMA	0.3 0.8	0.31 0.75	0.31 0.65	0.27 0.55	0.31 0.45	0.31 0.34	0.31 0.50	0.27 0.20	0.17 <0.05	41 wks (cracked) 0.06 <0.05
19	SRS38/15/4 (BDI(D1) 85% / ARA(D4) 15% / 4)	1019 (49°C)) 1021 (Control)) IMI 1020 (60°C))	Stearate Citrate Phthalate	NDPA NMA	0.3 0.8	0.29 0.75	0.29 0.65	0.25 0.45	0.28 0.45	0.30 0.34	0.32 0.45	0.22 0.20	(cracked) 0.12 Nil	

NOTE: All charges cellulose acetate inhibited, six inch diameter solids, stored vertically inside close-fitting aluminium tubes with tight-fitting polythene end caps, excepting items 1, 2, 4, 5, 8, 9, 11 and 17 which were part charges in sealed containers.

TABLE 7

PROPELLANT COMPOSITIONS (NOMINAL PERCENTAGE)

CPA	PYRO NC 12.6%N	NG	TA	DEP	SOA	EC	NMA	NOPA	Resorcinol	Lead Salts						MMA	Potassium Sulphate	Atomised Aluminium	Ammonium Perchlorate	Kieselguhr	Carbon Black	Graphite	CMP	Propellant Type and Powder Lot
										2-Ethyl Hexoate	Stearate	β-Resorcylate	Salicylate	Citrate	Phthalate									
2349	63.7	24.4	8.9			0.5				2.5												0.03		Carbamite Stabilised
2348	61.8	25.8	9.4			0.5				2.5								80 pyritic particlee per lb				0.03		" " (with pyritic particles)
2351	61.7	25.9	9.4					0.5		2.5												0.03		NDPA Stabilised
2350	62.0	25.7	9.3					0.5		2.5								80 pyritic particlee per lb				0.03		" " (with pyritic particles)
2353	64.0	24.2	8.8				0.5			2.5												0.03		NMA Stabilised
2352	63.9	24.3	8.8				0.5			2.5								80 pyritic particlee per lb				0.03		" " (with pyritic particles)
2385	48.1	28.2	8.0		7.5	1.0		0.4			2.7					2.2	1.9					0.03		AID(M11)/5 Carbamite stabilised
2382	48.3	28.0	8.0		7.5	1.0		0.4			2.7					2.2	1.9	80 pyritic particles per lb				0.03		AID(M11)/5 " " (with pyritic particlee)
2384	48.1	28.2	8.0		7.5		1.0	0.4			2.7					2.2	1.9					0.03		AID(M15)/5 NMA/NDPA Stabilieed
2383	48.5	27.8	7.9		7.5		1.1	0.4			2.7					2.2	1.9	80 pyritic particlee per lb				0.03		AID(M15)/5 " " (with pyritic particlee)
4055	39.4	47.2	8.2					1.0				2.0	2.0								0.2	0.03		ATN/19
4775	36.1	49.6	9.5				0.6	0.4				1.8	1.8								0.2	0.03		ATN MOD/19
4543	39.4	47.5	7.9				1.0					2.0	2.0								0.2	0.03		ATN/4 (M)
5645	38.3	45.7	7.9				1.0					1.9	1.9					3.1			0.2	0.03		ATN(D26)/19(M)
5619	38.0	45.9	8.0				0.7	0.3				1.9	1.9					3.1			0.2	0.03		ATN(D26)/19
5716	38.4	39.7	12.1		5.4		0.6	0.6						1.6	1.6							0.03		BDI(D1)/25(Mod 2)
5717	39.3	39.1	11.6		5.6		1.2							1.6	1.6							0.03		BDI(D1)/25(Mod 1)
5327	38.5	42.3	8.3		5.4		1.0		1.3					1.6	1.6							0.03		BDI(D1)Mod (2% Resorcinol in Powder)/19 (Mod NMA for 2NDPA)
6362	39.6	38.9	11.4		5.6		0.65	0.55						1.65	1.65							0.03		BDI(D1)/25Mod
6548	37.7	44.8	7.3				0.6	0.3	0.6			1.9	1.9					4.7			0.2	0.03		ATN(D27)/47
6546	51.8	24.7	7.2		8.0		1.1	0.3			2.9					2.0	2.0					0.03		AID(M15)/5
6557	50.4	27.4	8.2		7.8		1.1	0.3			2.8						2.0					0.03		AIO(M15)/19
6544	58.7	23.6	7.2		0.8		0.1	1.5			1.7					2.0	2.0					0.03	2.4	OIO(N2K)/5
6602	55.4	32.1	8.2				1.32	0.34			1.32				1.32							0.03		ARA(D4)/19
6708	43.0	40.1	8.1		4.5		0.8	0.3			0.27			1.33	1.6							0.03		SRS 38/20/19 (BDI(01)/19 80% + ARA(D4)/19 20%)
1MI	42.65	40.3	7.9		4.85		0.8	0.3			0.2			1.4	1.6							0.03		SRS 38/15/4 (BDI(01)/19 85% + ARA(D4)/19 15%)
1M1	38.5	38.1	11.2		5.2		0.6	0.4						1.5	1.5		3.0					0.03		BD1/(D2)/25
S 854	27.8	24.3	5.8				1.0											20.2	20.9			0.03		Cast (CRU type)
S 855	40.0						1.0											29.0	30.0			0.05		Casting Powder (CRU type)
S 910	55.6	30.6					1.0					2.8	2.8					6.9			0.3	0.05		Casting Powder (ATN(D27))
S 915	37.1	46.6	6.7				1.0					1.9	1.9					4.8			0.2	0.03		Cast (ATN(D27)/33)
Y3705	39.7	47.4	7.7				1.0					2.0	2.0								0.2	0.03		L382) Cast ATN(D20)/33 type
Y3707	35.9	50.1	9.2				1.0					1.8	1.8								0.2	0.03		L382/1)
Y3706	39.6	46.8	7.8				1.0		0.6			2.0	2.0								0.2	0.03		L383) Cast ATN(D20)/47 type
Y3708	32.8	51.8	10.4				1.0		0.6			1.6	1.6								0.2	0.03		L383/1)
S 900	27.5	24.1	5.7				1.0		1.0									20.0	20.7			0.03		Cast (CRU type)
S 905	39.6						1.0		1.0									28.7	29.7			0.05		Casting Powdar (CRU type)
Y3765	38.1	46.1	7.6				0.7	0.3				1.9	1.9					3.2			0.2	0.03		W 95/61 Cast ATN(D26)/4
T2039	40.4	46.9		7.5			0.7	0.3				2.0	2.0								0.2	0.03		L 382 Cast ATN(D20)/33 type
Y4130	38.0	45.4	7.4				0.7	0.3				1.9	1.9					3.2		1.0	0.2	0.03		L 347 Cast ATN(D26)/4 + 1% Kieselguhr
Y4153	38.3	45.4	7.4				0.7	0.3	0.7			1.9	1.9					3.2			0.2	0.03		L 422 Cast ATN(D26)/47 with Bishopton NC
Y4120	39.3	41.6	8.0		5.6		0.7	0.3						1.6	1.6					1.3		0.03		L 438 Cast BDI(D1)/25 + 1.3% Kieselguhr

NOMENCLATURE

CDB	Cast Double-Base
CMCDB	Composite Modified Cast Double-Base
DEP	Diethyl Phthalate
DMP	Dimethyl Phthalate
EC	Ethyl Centralite (Carbamite)
MMA	Methyl Methacrylate
NC	Nitrocellulose
NDPA	2-Nitrodiphenylamine
NG	Nitroglycerine
NMA	para-Nitro-N-methyl aniline
SOA	Sucrose Octa Acetate
SV	Silvered Vessel
TA	Triacetin

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Palmer G A
August 1971
17 pp, 7 tabs, no figs

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